Rocky Mountains Southwest Great Plains

Research Note RM-428

June 1983

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Annual Needle and Leaf Fall in an Arizona Mixed Conifer Stand

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Annual needle and leaf fall ranged from 0.02 to 1.90 tons per acre, with an average of 0.41 ton per acre. Sites dominated by ponderosa pine had the most needle fall, those dominated by Engelmann spruce-corkbark fir had the least. Other significant differences were determined between these sites and sites containing aspen or mixed conifers. Needle and leaf fall could not be correlated with stand basal area because of the normal variability encountered within mixed conifer stands.

Keywords: Needle-leaf fall, forest floor, forest fuels, mensuration, mixed conifer forests

Mixed conifer forests, which cover between 2 and 2.5 million acres in the Southwest, are important sources of timber, water, wildlife, range as well as recreational resources. A knowledge of forest floor characteristics, such as depth, weight, and rate of accumulation, is important, because they influence tree regeneration, site preparation needs, herbage production, and hydrological characteristics of a site. The forest floor also serves as a storehouse of essential nutrients. Forest floor characteristics are also of importance to fire prevention and control, because they affect fire behavior and its effects, fuel management, and preattack planning (Sackett 1979).

Needle and leaf material is the major component by weight of the forest floor's highly combustible fine fuels (material up to 1 inch in diameter) and an important component of the total dead fuel load. In a study of 16 southwestern mixed conifer stands, Sackett (1979) found that 17.3 tons per acre of needles made up 78% of the fine fuels in the total forest floor and 38% of the weight of all fuels. Needle and leaf material (1.1 tons per acre) were approximately 30% of the surface fuels in the top or L layer. This layer contains small branches, twigs, bark, and cone parts, as well as the needles and leaves which have not decayed sufficiently to lose their identity.

Annual needle and leaf fall is a major part of the L layer, and the process by which the forest floor is continuously renewed. Bray and Gorham (1964) report that foliage makes up between 60% and 76% of the total annual litter fall. The rate of accumulation thus influences fire characteristics and site quality. A knowledge of accumulation rates would be useful in the development and validation of computer simulation models relating forest floor changes to fire and site parameters. Such information would also be of interest to researchers studying forest floor dynamics and nutrient relationships.

Kittredge (1948) maintained that an accurate measurement of litter fall cannot be obtained by studying the L layer but requires collections in trays or burlap strips. Needle and leaf fall has not been studied in Arizona mixed conifer stands, although work has been conducted in southwestern ponderosa pine (*Pinus ponderosa*) stands by Davis et al. (1968), and has been reported for total litter fall, from several other forest types by Kittredge (1948), Tarrant et al. (1951), and by Bray and Gorham (1964).

This exploratory study was established in an eastern Arizona mixed conifer stand to obtain some basic needle fall data. A second objective was to relate needle fall to stand parameters such as composition, and various den-

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sity (trees or basal area per acre) variables. Such relationships would allow for the indirect estimation of needle fall by using commonly measured forest stand parameters.

Study Area and Methods

The study was conducted on a 108-acre virgin area within the West Fork of Willow Creek. The 290-acre watershed is in east-central Arizona, 25 miles south of Alpine. The mixed conifer forest (table 1) contains seven coniferous and one deciduous species: Engelmann spruce (*Picea engelmannii*), blue spruce (*P. pungens*), Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), white fir (*Abies concolor*), corkbark fir (*A. lasiocarpa* var. *arizonica*), ponderosa pine, southwestern white pine (*Pinus strobiformis*), and quaking aspen (*Populus tremuloides*). Douglas-fir, Engelmann spruce, and aspen made up over 84% of the trees and 72% of the basal area on the area. The forest contains a small patch mosaic of different stand structures and species compositions. Some patches may be dominated by one species (e.g., ponderosa pine or aspen), while an adjacent patch may contain all eight species. The overall stand is considered uneven-aged. Total point basal areas varied from less than 25 to more than 400 square feet per acre. Average total tree volume per acre was about 24,800 fbm.

Table 1.—Mean annual litter fall, with standard error, and stand characteristics for the main study area

	Number of sample points	Annual litter fall (tons/acre)	- Per acre basis - number of trees	basal area (ft²)
Total study area	59	0.41 ± 0.04	396	202
Mixed conifer	28	0.39 ± 0.05	453	206
Engelmann spruce/ corkbark fir	15	0.17 ± 0.02	289	208
Ponderosa pine	8	0.86 ± 0.21	185	147
Quaking aspen	8	0.49 ± 0.06	674	238

Soils on the watershed are derived from basalt parent materials and are a stony, silty, clay loam. Elevations range from 8,900 to 9,200 feet, slopes are generally between 20% and 30%, and aspects are mainly southeast or north- to northwest-facing. Annual precipitation is about 29 inches, with 50% falling as snow between November and April.

The study area was in the middle third of the watershed. Needles and leaves were collected on 18-inch-square pieces of 1/4-inch galvanized hardware cloth placed randomly under the canopy, at 61 permanently located timber inventory sample points, established on survey lines which crossed the watershed perpendicular to the main drainage channel.

The sample points were classified by aspect or into categories based on predominant species, i.e., ≥50% of the point basal area. The four species categories within the general mixed conifer stand were mixed conifer (47% of the total), Engelmann spruce-corkbark fir (25%), ponderosa pine (14%), and quaking aspen (14%). The four categories were scattered in small groups throughout the area, and could change from point to point along a survey line. Some stand characteristics for the four species categories are presented in table 1. Mixed conifer included points occupied by Douglas-fir and white fir or by a combination of species where no one species was predominant. However, Douglas-fir and white fir made up more than 60% of the trees and basal area in this category. Engelmann spruce and corkbark fir were more than 80% of the trees and basal area in that category (fig. 1). Ponderosa pine dominated the sawtimber size class and total basal area on its sites; however, Douglas-fir was most common among the understory trees. The aspen stands were generally smaller than 18 inches d.b.h., but also contained many Douglas-fir and white fir saplings and small poles. Plots were established in late fall 1976 and were measured periodically from early May through November 1977. There was some overlap because November 1976 was included in the first measurement period; however, collections during this month should have been minor, because litter fall is finished by the end of October. Samples from several years would have been better; however, the current effort is still of value because of the lack of other litter fall information from these forests. Care was taken to collect any needles which might have fallen through the mesh. Woody material was not included in the sample. No attempt was made to divide the needle and aspen leaf material by species. Two plots were later discarded because of excessive red squirrel (*Tamiasciurus hudsonicus*) disturbance. Samples were brought into the laboratory to determine oven-dry weights. Weights were related to expressions of stand composition and density, which were obtained from a timber inventory which utilized standard point sampling techniques based on a 25 basal area factor (BAF) angle gage.

Needle accumulation and stand parameters data were analyzed using regression techniques. Linear and curvilinear models were tested. Analysis considered all data or various subsets of data. Differences among species categories were compared by one-way analysis of variance techniques, using logarithmic transformations (base 10) of the basic data. Significance for all analyses was indicated by values above the 5% level.

Results and Discussion

The annual needle and aspen leaf fall for the Willow Creek mixed conifer study area ranged from 0.02 to 1.90 tons per acre, with an area coverage of 0.41 ± 0.04 (standard error). Although, managers and planners are generally more interested in the larger, more mapable units of land, the area's component species categories showed some interesting differences (table 1). Annual

Figure 1.—Engelmann spruce-corkbark fir area within the Willow Creek mixed conifer stand.

leaf and needle fall was similar between ponderosa pine and aspen; however, ponderosa pine sites produced significantly more needle fall than either mixed conifer or Engelmann spruce-corkbark fir sites. Differences between aspen and spruce-fir and between mixed conifer and spruce-fir were also significant. Aspen and mixed conifer categories were similar. Although the sample sizes were small, these results are not that surprising when ponderosa pine needles, which are large and usually fall in groups of three, are compared with the relatively small needles of the other conifers. Number of needles dropped would be another factor, although this was not studied. Ponderosa pine tends to drop 1/3 of its needles every year while Douglas-fir and spruce may drop less than 1/5 every year. Aspen is deciduous and produces a continuous mat of leaves each October. The mixed conifer category occupied a middle position between ponderosa pine and spruce-fir values. This is also not surprising, because this category contains trees of all species, including spruce, pine, and aspen.

More than 70% of the needles and leaves fall from September through November (table 2). The percentage varied by category; 86% of the aspen and spruce-fir foliage fell during this period, compared to 65% for pine and mixed conifers. Twenty-four percent of the needles in the latter categories fell during the winter and early spring. This additional period could be related to squirrel activity or to the effects of snow and wind activities. Needle-leaf fall from May to September was minor, about 10% of the total; it varied from 6% in the spruce-fir to 12% in the mixed conifers.

Annual needle and leaf fall values are not available from other mixed conifer stands; however, some of the component categories can be compared. The 0.86 ton per acre value for ponderosa pine is lower than a value reported for pure ponderosa pine stands near Flagstaff, Ariz. (Davis et al. 1968), where an average of 1.8 tons per acre were collected. The Willow Creek value is nearer the 0.94 ton per acre reported for pure ponderosa pine in California (Bray and Gorham 1964) and higher than the 0.27-0.36 ton per acre range reported for this species in the Pacific Northwest (Tarrant et al. 1951). Kittredge (1948) reported that annual accumulations decreased with decreased site index and with increased elevation. Bray and Gorham (1964) showed that annual litter production decreased with increased latitude. They attributed the relationship to differences in temperature, amount of insolation, and the effect on growing season. The Willow Creek ponderosa pine measurements tend to follow these general observations. Willow Creek is further south and at a higher elevation than the other sites. It is about 2,000 feet higher than Flagstaff. Ponderosa pine is also off-site at Willow Creek, where it is a seral phase on mixed conifer sites, which will eventually convert to Douglas-fir as the pine overstory dies or is harvested (fig. 2). Aspen leaf fall (0.49 ton per acre) is, however, lower than values reported for New Mexico (0.79 ton per acre) by Gosz (1980) or for Utah (0.62 ton per acre) by Bartos and DeByle (1981). Needle fall values for Rocky Mountain spruce and fir species were not reported in the review papers (Bray and Gorham 1964, Kittredge 1948).

Other factors besides species composition, site quality, and location affect annual litter production. Kittredge (1948) reported that old growth longleaf pine (*P. palustris*) in Florida produced 0.5 ton per acre compared to between 1.2 and 1.5 tons per acre for second growth stands. An age relationship would be difficult to determine in the uneven-aged stands at Willow Creek.

Table 2.—Mean litter fall (tons per acre), with standard error, by collection periods for the main study area

	11/76-5/77	5/77-7/77	7/77-9/77	9/77-11/77
Total study area	0.08 ± 0.01	0.02 ± 0.00	0.02 ± 0.00	0.29 ± 0.03
Mixed conifer	0.09 ± 0.02	0.03 ± 0.01	0.02 ± 0.00	0.25 ± 0.02
Engelmann spruce/ corkbark fir	0.01 ± 0.00	0.01 ± 0.00	Trace	0.15 ± 0.02
Ponderosa pine	0.21 ± 0.05	0.05 ± 0.02	0.04 ± 0.01	0.56 ± 0.13
Quaking aspen	0.03 ± 0.01	0.03 ± 0.00	0.01 ± 0.00	0.42 ± 0.05

Figure 2.—A typical example of a ponderosa pine overstory with vigorous Douglas-fir in the understory on a mixed conifer site near the Willow Creek study area.

All attempts to relate annual needle and leaf accumulation to basal area, trees per acre, and various other stand parameters were unsuccessful. Regression relationships were generally non-significant or if significant, resulted in such low coefficients of determination (r^2) that they were not practical. Other researchers have similarly been unable to relate L-layer and other forest floor weights to forest basal area. Sackett (1979) was unable to relate dead fuel loadings in 62 ponderosa pine and 16 mixed conifer stands to basal area. Ffolliott et al. (1977), working in a 1,275-acre mixed conifer forest, which included Willow Creek, were also unable to relate litter depth or weight to forest basal area; they did develop statistically significant relationships between the other forest floor layers and total forest floor and basal area, but the correlations were not high. Sackett (1979) attributed the difficulty in developing usable statistical relationships to the inherent variability of both the stands and the forest floor within undisturbed southwestern forests. Coefficients of variation for fuel loading within the 62 intensively sampled ponderosa pine sites ranged from 46% to 131%. The overall coefficient for mixed conifer needles in the L-layer was 45% (Sackett 1979). The overall coefficient for the Willow Creek site was 84%, while the coefficients of variation for the species categories ranged from 33% for aspen to 69% for ponderosa pine. Attempts to relate basal area to fuel weights and litter accumulation have been more successful in more homogeneous stands. For example, Dieterich (1963) was able to develop a relationship for red pine (*P. resinosa*) plantations in the Lake States.

The resulting needle and leaf accumulation values from Willow Creek, although for only 1 year, can be used as first approximations in similar mixed conifer stands. More refined or site-specific values will require intensive sampling, especially in the absence of usable statistical relationships between needle accumulation and forest parameters in heterogeneous forest stands.

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